

Deception Pass Log Rail

by

Omar W. Jepperson

Washington State Department of Transportation
P.O. Box 330310
Seattle, WA 98133-9710

Phone - (206) 440-4237

Fax - (206) 440-4803

jepperO@wsdot.wa.gov

William F. Williams

Crashworthy Structures Program - Riverside, Room 7091
Texas Transportation Institute
Texas A&M University System 3135 TAMU
College Station, TX 77843-3135

Phone - (979) 862-2297

Fax - (979) 845-6107

w-williams@tamu.edu

Richard B. Albin

Washington State Department of Transportation
P.O. Box 47329
Olympia, Washington 98504-7329

Phone - (360) 705-7269

Fax - (360) 707-6815

AlbinD@wsdot.wa.gov

D. Lance Bullard, Jr.

Crashworthy Structures Program - Riverside, Room 7091
Texas Transportation Institute
Texas A&M University System 3135 TAMU
College Station, TX 77843-3135

Phone - (979) 845-6153

Fax - (979) 845-6107

l-bullard@tamu.edu

Submitted for presentation at the 84th Annual Meeting of the Transportation Research Board, Washington D.C.
2005.

Estimated Word count: 4250 text.

Deception Pass Log Rail

Omar Jepperson
Washington State Department of Transportation

William Williams
Texas Transportation Institute

Richard B. Albin
Washington State Department of Transportation

D. Lance Bullard, Jr.
Texas Transportation Institute

ABSTRACT

Washington State Route 20 in northwest Washington passes through the Deception Pass State Park. The Civilian Conservation Corps (CCC) constructed the portion of SR 20 within the park in the mid 1930's. As part of this work, the CCC constructed a stone masonry bollard and log rail system to delineate the edge of the road and prevent early model vehicles from leaving the roadway (see Figure 2). Due to their age, quality of workmanship, and importance to the surroundings, the bridges and log rails are eligible for the National Register of Historic Places.

Previous attempts to replace this rail with a crashworthy system were unsuccessful due to concerns for preserving the aesthetic and historic integrity of the park. A new approach was adopted that began with understanding the context of the highway and the concerns of the other stakeholders. In addition, the stakeholders were educated on the safety issues. As a result, a solution was developed that was acceptable to all of the stakeholders. The primary solution involved the development of a new barrier that replicated the appearance of the original log rail. This barrier was crash tested in accordance with the NCHRP Report 350 TL-2 criteria and is available for use in other locations where an aesthetic barrier is desired.

Keywords: guardrail, barrier, log rail, timber rail, wood rail, crash test, aesthetic, context sensitive

Deception Pass Timber Barrier

HISTORICAL BACKGROUND AND SETTING

Washington State Route 20 is an NHS highway providing the most northerly east-west route in Washington State. In Northwest Washington, SR 20 passes through Deception Pass State Park and provides the only highway connection between Whidbey Island and the mainland.



FIGURE 1 Deception Pass Bridge.

Deception Pass State Park is a 4,134-acre marine and camping park with 77,000 feet of saltwater shoreline, and 33,900 feet of freshwater shoreline on four lakes. Two bridges carry SR 20 over Deception and Canoe passes (see Figure 1). The park includes sheer cliffs, water views, old-growth forests and abundant wildlife and is the most popular state park in Washington.

The portion of SR 20 within the park was constructed by the Civilian Conservation Corps (CCC) in the mid 1930's. As part of this work, the CCC constructed a stone masonry bollard and log rail system to delineate the edge of the road and prevent early model vehicles from leaving the roadway (see Figure 2). Due to their age, quality of workmanship, and importance to the surroundings, the bridges and log rails are eligible for the National Register of Historic Places.



FIGURE 2 CCC bollard and log rail system.

TRAFFIC AND ACCIDENT HISTORY

The highway usage has changed significantly since the Civilian Conservation Corps (CCC) built the road in the mid 1930's. Currently, the ADT is 15,000 and the 85 percentile speeds vary between 36 and 45 MPH. Within the 2-mile segment of SR 20 inside Deception Pass State Park, there were 10 accidents per year in 1980 and 22

accidents per year in 2000. Fifty percent (or approximately 11) of the accidents involved vehicles hitting fixed objects on the roadside. Forty five percent of these “hit fixed object” accidents involved the log rail system (approximately 5 per year). Sixty percent of the accidents involving the rail result in an injury. Most accidents occur during the summer months during peak tourist season. As a result of this history, this section of roadway is considered a High Accident Corridor (HAC).

DESIGN PROCESS

In the early 1990’s a project was initiated to replace the log rail with a crashworthy barrier system. At that time it was proposed to install a W-Beam guardrail. However, significant concerns were raised by the Washington State Parks and Recreation Commission (WSPRC), which stated, “State Parks does not approve of the proposal to remove these guardrails or of plans that would destroy the historic integrity of this site.” Due to the resistance from the WSPRC the project was cancelled.

In 2000, a new project was initiated to address the safety concerns discussed previously. This time, an aesthetic, steel backed timber guardrail was proposed. However, the WSPRC again felt that removing the historic log rail system and replacing it with steel-backed timber guardrail would compromise the integrity of the park and they did not give the proposal a warm reception.

It was at this point that WSDOT started to approach this project differently. The WSDOT design team realized that because of the previous attempts to remove the historic log rail, the WSPRC did not feel that there was an understanding of the concerns. Conversely, the WSDOT did not feel that there was an understanding of the safety concerns. To reach a solution that would be acceptable, the WSDOT assured the stakeholders that new alternatives would be considered and evaluated before choosing a preferred solution.

WSDOT brought stakeholders together for a series of meetings with representatives from Island County Public Works, South Whidbey Historical Society, Washington State Parks and Recreation, State Office of Archaeology and Historic Preservation (OAHP), WSDOT, FHWA and Washington State Patrol. At the initial meeting the following process was agreed upon:

- Develop mission statement
- Brainstorm solutions
- Investigate feasibility of solutions
- Educate stakeholders on roadside safety
- Define character defining features
- Develop decision matrix
- Complete decision matrix with facilitator
- Complete additional investigation
- Select preferred solution

The group adopted the following mission statement for this project:

Reduce the number and severity of injury accidents, while maintaining the integrity of the park.

The adoption of a mission statement was very important to this process as it helped keep the team focused. The team brainstormed 27 different alternatives to meet the mission. The team then constructed a decision matrix to step through the assessment of each brainstormed alternative, agree on a quantitative score, and reach and agree on the optimal decision. Criteria used for selecting preferred alternative were: Retention of Character Defining Features, Ease of Maintenance, Reduces Severity of Accidents, Reduces number of accidents, Aesthetics. A facilitator assisted the group in separating solutions into guardrail and non-guardrail solutions to “further investigate” and ones that deserved no further investigation. At this point, based on input from barrier design experts, it was determined that it was not feasible to retrofit the existing rail to make it crashworthy. The products of the decision matrix were 9 non-barrier related solutions to further investigate, 3 barrier related solutions to further investigate, and 15 solutions that warranted no further investigation.

There was a considerable effort to increase the understanding of the team on roadside safety concerns as well as the aesthetic and historical concerns for this location. After reviewing the accident history and the background on roadside safety tools such as crash testing, the team agreed that some type of improvement to the rail was appropriate. It was also agreed that this improvement needed to be sensitive to the park context.

As WSDOT incorporated WSPRC and OAHP’s ideas and listened to their concerns, the barriers of the initial adversarial relationship disappeared. Three solutions rose to the top for further analysis and consideration. The development of a new barrier system that replicated the original log rail system was the primary solution. In

addition, WSDOT will work with WSPRC to improving signing in the park and a highway advisory radio system has been constructed to the north of the project site.

It was also agreed that a 250' section of original rail will be left in place to allow visitors to view the original system and rocks from some of the original bollards will be used in the construction of the new system. The original CCC guardrail system will be documented and archived according to Historic American Engineering Record (HAER) Level 2 documentation and interpretive signs will be constructed near the preserved section of rail

BARRIER DESIGN

The integrity of the park is linked to maintaining character-defining features of the original CCC rail. WSPRC said that, “Deception Pass State Park is the State’s finest example of CCC park construction. For those visitors passing through on Highway 20, the guardrails may be the only evidence of CCC work they will see.” To provide direction for the development of a replacement railing the team identified 10 character-defining features of the original CCC rail. The character defining features were as follows:

- 1) The bollards (supports) are constructed of rock and mortar
- 2) The bollards have a distinctive shape (batter, shoulders, approximate dimensions)
- 3) Roadway users have the ability to see over and under the rail
- 4) The log rails are wood
- 5) The bollard spacing is about 18 feet
- 6) Because they are hand crafted, the bollards are non-uniform
- 7) The log is discontinuous and aligned at the center of the bollards
- 8) The log rail sits on the bollard’s shoulders
- 9) The logs have taper
- 10) The spacing of the bollards is non-uniform.

The WSDOT contracted with the Texas Transportation Institute (TTI) to develop a crashworthy barrier that incorporated as many of these character-defining features as possible. It was assumed that since a rock support was desired, the barrier would have to be a rigid system with little or no deflection. The barrier design would be tested in accordance with the National Cooperative Highway Research Program (NCHRP) Report 350 (1) criteria for Test Level 2 conditions. For Test level 2 conditions, a design force of 27 kips distributed over a distance of four feet was

used to design the log rail and supports, in accordance with the AASHTO LRFD Bridge Design Specifications (2). In addition to a conventional ultimate strength analysis of the log rail, structural computer modeling of the log rail design was performed using the structural engineering program RISA-3D.

The barrier that was developed consisted of a steel backed log that is supported by stone fascia bollards (see Figure 3). The steel backed timber log rail consisted of 12-inch diameter “turned” Douglas Fir logs. The logs were sawn with a 6-inch flat back to accommodate a 6-inch wide by 3/8 inch thick steel plate. The plates were attached to the back of the log using wood lag screws. The height to the top of the log is 27 inches from the ground.



FIGURE 3 Prototype Barrier

The bollards were designed with a natural stone facade over a reinforced concrete core, footing, and an 18” diameter reinforced concrete shaft. It is expected that this foundation may be modified depending on site conditions (depth of rock, etc.). The stone supports were designed for an 18 foot maximum spacing and may be installed at lesser spacing to give the barrier a non-uniform appearance. To achieve the 18 foot spacing, it was determined, based on the analyses and computer modeling, that an intermediate support was necessary. The intermediate support consists of a steel pipe support with a reinforced concrete shaft foundation. The initial design used an 8” diameter pipe. However, in the final design, this was changed to a 6” pipe to make it less noticeable.

In the initial design, each end of the logs were attached to the bollards with two 7/8 inch diameter bolts (4 bolts on each bollard) that bolted through the logs and steel plates and connected to anchors which were embedded into the concrete core walls within the stone-faced bollards. However, during construction of the test installation, this design proved to be very difficult to construct. As a result, the connection was modified to include two shorter (2 1/2 inches long) 7/8-inch diameter bolts, which were used to secure the 3/8-inch thick steel splice plate to the bollards. The logs were “notched” four inches on each end and the adjoining steel backed plates were shortened by the same amount to accommodate the connection of the steel splice plates to the bollards. The steel backed logs were then secured to the steel splice plates using three 3/4-inch diameter bolts that bolted through the logs with steel-backed

plates and through the steel splice plates. A third bolt was added on each ends of each log to increase the capacity of the connection between the steel-backed logs and steel splice plates.

This design incorporated 6 of the 10 character defining features that were previously identified. Details of the final design are shown on Figure 8.

NCHRP 350 COMPLIANCE TESTING

NCHRP Report 350 provides guidance for conducting crash tests to evaluate highway safety features. NCHRP Report 350 has 3 test levels that are based on the speed of the impacting vehicle. Test Level 2 (TL-2) uses a speed of 70 km/h (43 mph) and this is appropriate for this section of highway. According to NCHRP Report 350, two crash tests are typically performed to evaluate longitudinal barriers to TL-2, one with an 820 kg (1800 pound) small car (test 2-10) and the other with a 2000 kg (4400 pound) pickup truck (test 2-11).

The small car test is primarily to assess occupant risk and with a rail system, a primary concern is for snagging on the supports. Based on a review of other steel backed timber rails that have already been approved by FHWA (4), it was determined that this test was not necessary. The barrier will have approximately 12" of separation from the front edge of the log to the support, which is more than other timber rails, and with a TL-2 speed of 70 km/h (43 mph), it was decided that this barrier would perform at least as well as the other approved barriers with this vehicle.

The pickup truck test is intended to evaluate the strength of the section for containing and redirecting the pickup truck.

A 126 foot long test installation was constructed to evaluate the performance of this barrier. Two tests were performed and are summarized as follows.

Test 400561-1 (5)

Test Description

The initial design described previously was tested with a 4514 lb (2050 kg) pickup truck, traveling at a speed of 44.5 mi/h (71.6 km/h). The vehicle impacted the Deception Pass Log Rail 3.3 ft upstream of the leading edge of bollard 5, at an impact angle of 25.1 degrees. This impact location was determined to be the critical impact point to evaluate the potential for snagging of the tire on the rigid bollards. At 0.040 s after impact, the left front tire began to travel under the log rail element, and at 0.050 s, the vehicle began to redirect. The left front tire contacted and snagged on the leading edge of bollard 5 at 0.055 s, and the right front tire and wheel turned in toward the rail. At

0.271 s, the front of the vehicle lost contact with the log rail element, and at 0.337 s, the vehicle was traveling parallel with the rail at a speed of 29.7 mi/h. The rear of the vehicle contacted the rail element at 0.368 s. At 0.670-s, the vehicle lost contact with the log rail element and was traveling at an exit speed of 26.8 mi/h and an exit angle of 11.6 degrees. As the vehicle continued forward, it yawed counterclockwise and contacted the log rail again at 2.139 s. The vehicle subsequently came to rest adjacent to the end of the installation.

Damage to Test Installation

Damage to the log rail was primarily to the timber log element, as shown in Figure 4. The log element was gouged to a maximum depth of 0.8" near bollard 5. Tire marks extended 3.5" under the log element just downstream of the splice at bollard 5. Bollard 5 was pushed toward the field side 0.4". The vehicle was in contact with the log element for 11.5'. Maximum dynamic deflection was not measurable.



FIGURE 4 Barrier damage from test 400561-1.

Vehicle Damage

The left front quarter of the pickup truck sustained most of the damage, as shown in Figure 5. Structural damage was imparted to the left upper and lower A-arm, left outer tie rod, and left frame rail. Also damaged were the front bumper, grill, left front quarter panel, left front tire and wheel rim, left door, and left rear wheel rim. Maximum exterior crush to the vehicle was 25.0" in the frontal plane at the left front corner near bumper height. Maximum occupant compartment deformation was 2.3" in the center front floorpan over the transmission tunnel



FIGURE 5 Vehicle damage from test 400561-1.

Occupant Risk Values

In the longitudinal direction, the occupant impact velocity was 21.0 ft/s at 0.131 s, the maximum 0.010-s ridedown acceleration was -4.0 g's from 0.140 to 0.150 s, and the maximum 0.050-s average was -8.7 g's between 0.064 and 0.114 s. In the lateral direction, the occupant impact velocity was 17.1 ft/s at 0.131 s, the highest 0.010-s occupant ridedown acceleration was 4.0 g's from 0.464 to 0.474 s, and the maximum 0.050-s average was 7.8 g's between 0.063 and 0.113 s.

This test met all of the evaluation criteria in NCHRP Report 350. A summary of the test information is shown on Figure 9.

Test 400561-2 (6)

While the crash performance of this design was acceptable, there were some concerns about the constructability of this system and a few modifications were made to the steel backed log rail design as was discussed previously. As a result of these modifications, an additional test was performed to ensure the changes did not affect the performance of the system.

Test Description

The final design was tested with a 4529 lb (2056 kg) pickup truck, traveling at a speed of 44.7 mi/h (71.9 km/h). The vehicle impacted the Deception Pass Log Rail with the right front corner of the front bumper at the location of the centerline of post 6 and at an impact angle of 24.4 degrees. This impact location was determined to be the critical impact point to evaluate the strength of the intermediate support since the first test established that snagging on the bollards was not critical. At approximately 0.045 s after impact, the right front tire and wheel rim gouged into the timber rail, snagging slightly, and by 0.056 s after impact, the pickup truck began to redirect. The front of the vehicle lost contact with the timber rail at 0.291 s, and at 0.392 s, the vehicle was traveling parallel with the installation and traveling at a speed of 26.0 mi/h. The rear of the vehicle contacted the timber rail at 0.467 s. At 0.708 s, the vehicle lost contact with the timber rail, and was traveling at an exit speed of 22.0 mi/h and an exit angle of 6.5 degrees. The vehicle subsequently yawed towards the installation and contacted the timber rail a

second time at 1.376 s. The vehicle came to rest adjacent to the timber rail at post 13, approximately 60 ft downstream of impact.

Damage to Test Installation

Damage to the log rail was primarily to the timber log element, as shown in Figure 6. The log element was gouged and tire marks extended along the face of the log. Bollard 6 was disturbed only. The vehicle was in contact with the log element 12.5 ft. Maximum dynamic deflection was not measurable.



FIGURE 6 Barrier damage from test 400561-

Vehicle Damage

The right front quarter of the pickup truck sustained most of the damage, as shown in Figure 7. Structural damage was imparted to the right upper A-arm, right side floor pan, and right frame rail. Also damaged were the front bumper, grill, right front quarter panel, right front tire and wheel rim, and right door. Maximum exterior crush to the vehicle was 23.6“ in the frontal plane at the left front corner near bumper height. Maximum occupant compartment deformation was 2.5” in the center front floor pan over the transmission tunnel.



FIGURE 7 Vehicle damage from test 400561-

Occupant Risk Values

In the longitudinal direction, the occupant impact velocity was 23.0 ft/s at 0.135 s, the maximum 0.010-s ridedown acceleration was -4.2 g's from 0.135 to 0.145 s, and the maximum 0.050-s average was -8.9 g's between 0.063 and 0.113 s. In the lateral direction, the occupant impact velocity was 16.7 ft/s at 0.135 s, the highest 0.010-s occupant ridedown acceleration was -3.9 g's from 0.135 to 0.145 s, and the maximum 0.050-s average was -6.8 g's between 0.061 and 0.111 s.

This test met all of the evaluation criteria in NCHRP Report 350. A summary of the test information is shown on Figure 10.

CONCLUSIONS

After several failed attempts to replace an old non-crashworthy railing in the Deception Pass State Park, the WSDOT took a different approach that engaged the stakeholders and jointly developed a solution. A very deliberate process was followed that helped ensure that all of the stakeholders understood the other stakeholders concerns. With an understanding of the safety issues related to the state highway and the scenic and historic issues that are a major concern in the park, an acceptable solution was developed that included the development of a new barrier that replicated, to the extent possible, the appearance of the original barrier. This barrier was crash tested in accordance with the NCHRP Report 350 TL-2 criteria and is available for use in other locations where an aesthetic barrier is desired.

REFERENCES

1. H.E. Ross, Jr., D.L. Sicking, R.A. Zimmer, and J.D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.
2. *LRFD Bridge Design Specifications*, Section 13, American Association of State highway and Transportation Officials (AASHTO), Washington, D.C., 2002 Interim.
3. Rapid Interactive Structural Analysis – 3 Dimensional (RISA – 3D), Version 4.5, RISA Technologies, Foothill Ranch, California
4. *NCHRP Report 350 Aesthetic Barriers and Bridge Rails*, Memorandum HAS-10/B-64D2, Federal Highway Administration, Washington D.C., February 12, 2004.
5. D. Lance Bullard, Jr., William F. Williams, Wanda L. Menges, Rebecca R. Haug, Development, *Testing And Evaluation of The Deception Pass State Park Log Rail*, Project No. 400561-1, Texas Transportation Institute, Texas A&M University System, College Station, September, 2003.

6. D. Lance Bullard, Jr., William F. Williams, Wanda L. Menges, Rebecca R. Haug, *Testing And Evaluation of The Deception Pass State Park Log Rail*, Project No. 400561-2, Texas Transportation Institute, Texas A&M University System, College Station, July, 2004.

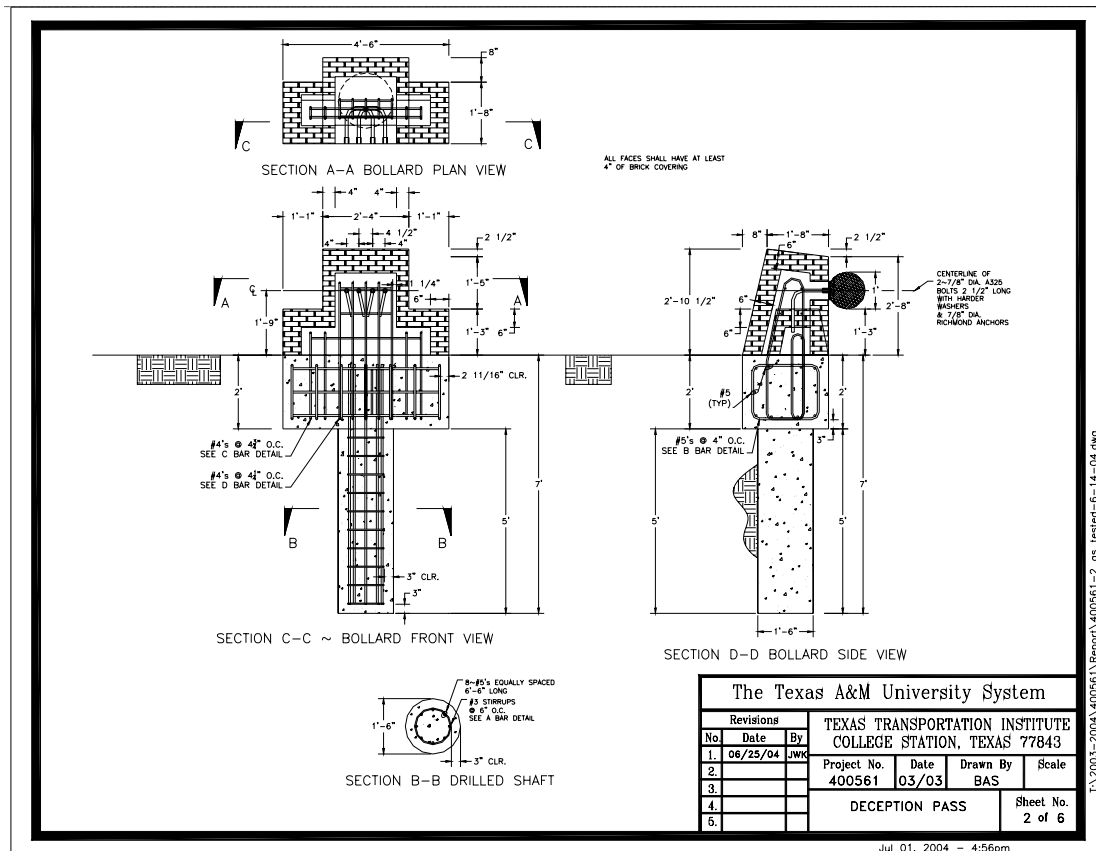
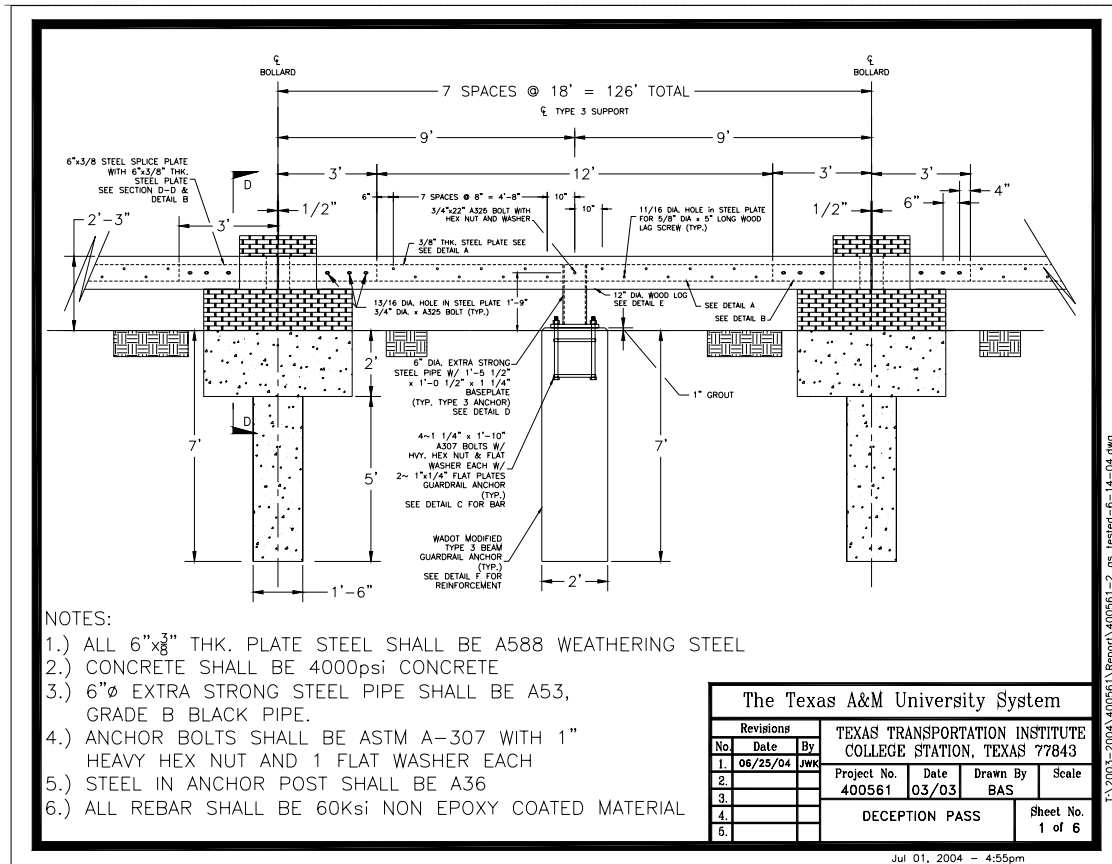


FIGURE 8 Deception Pass Log Rail details.

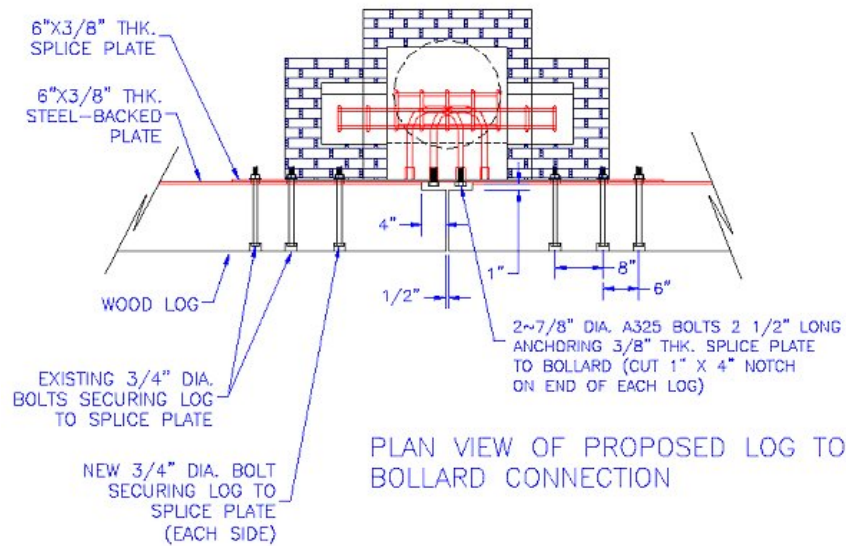
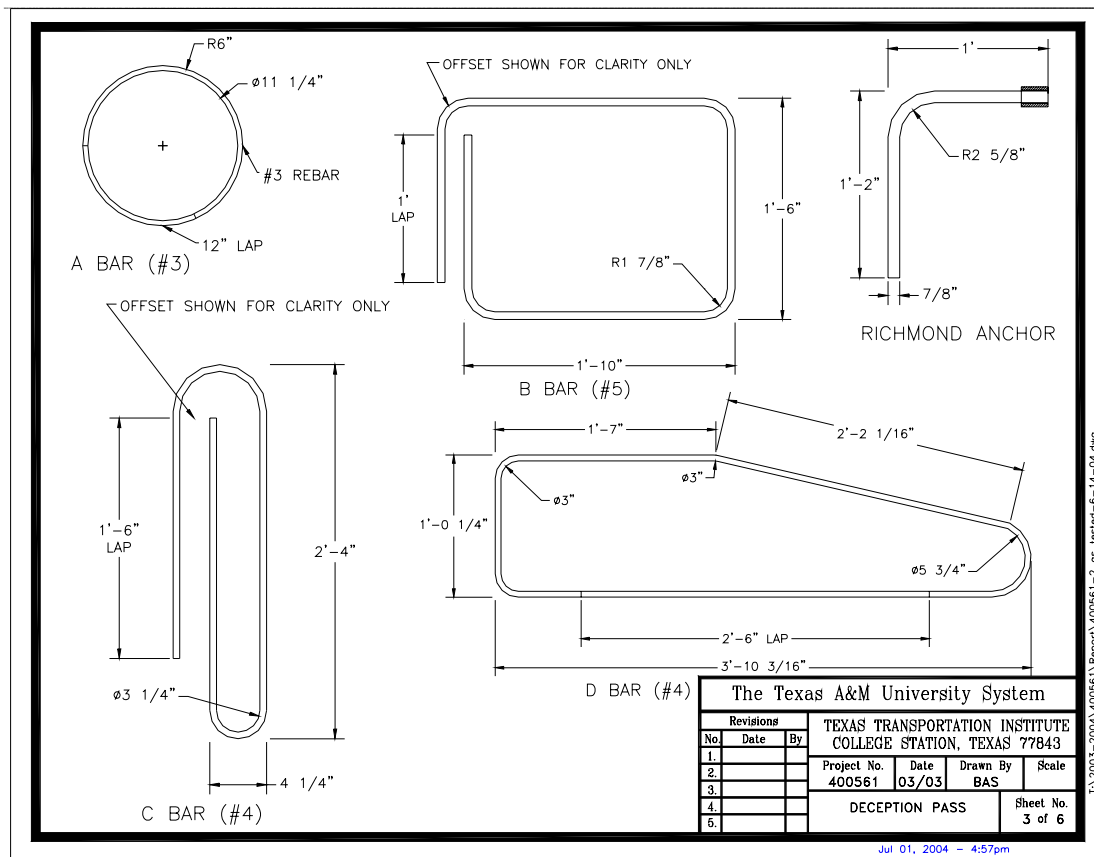


FIGURE 8 (continued) Deception Pass Log Rail details.

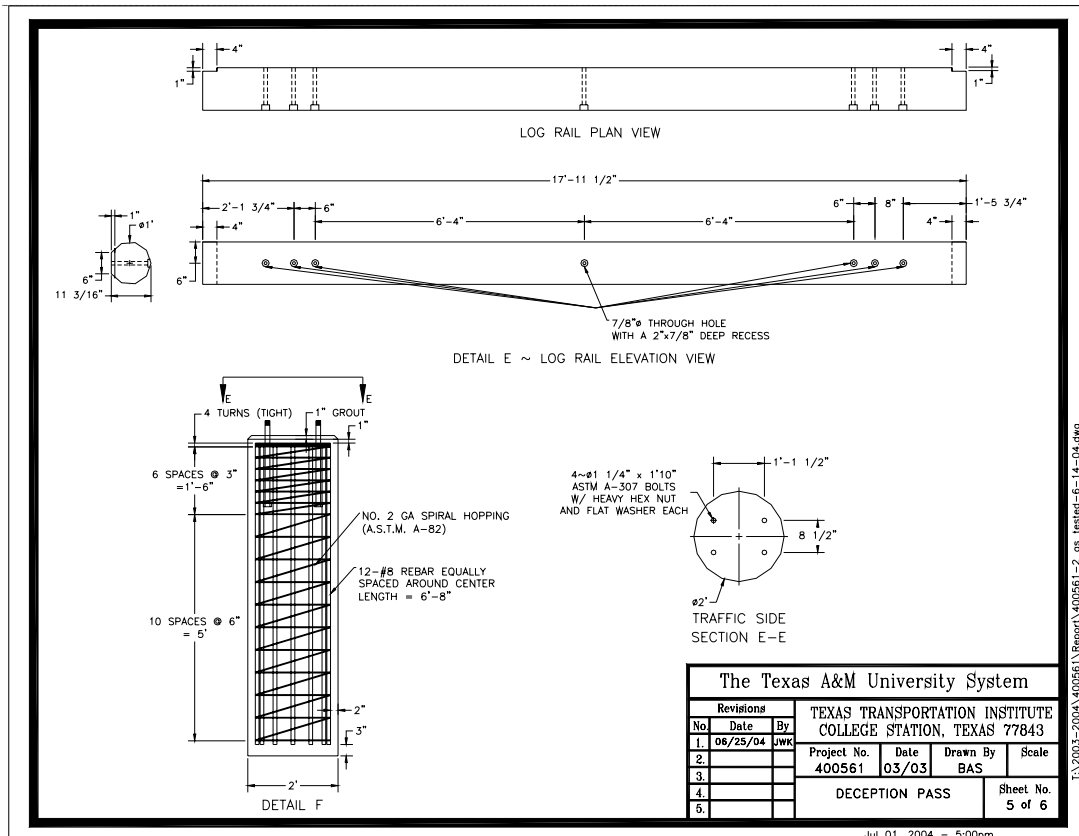
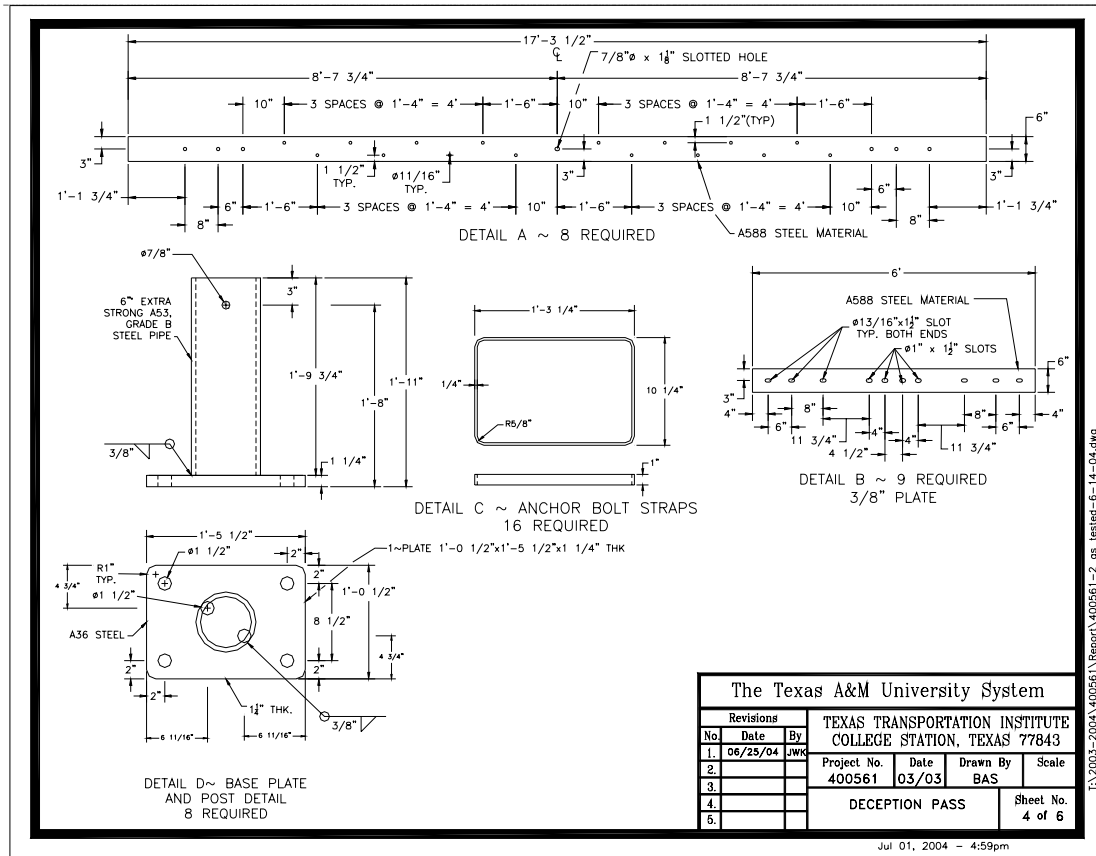
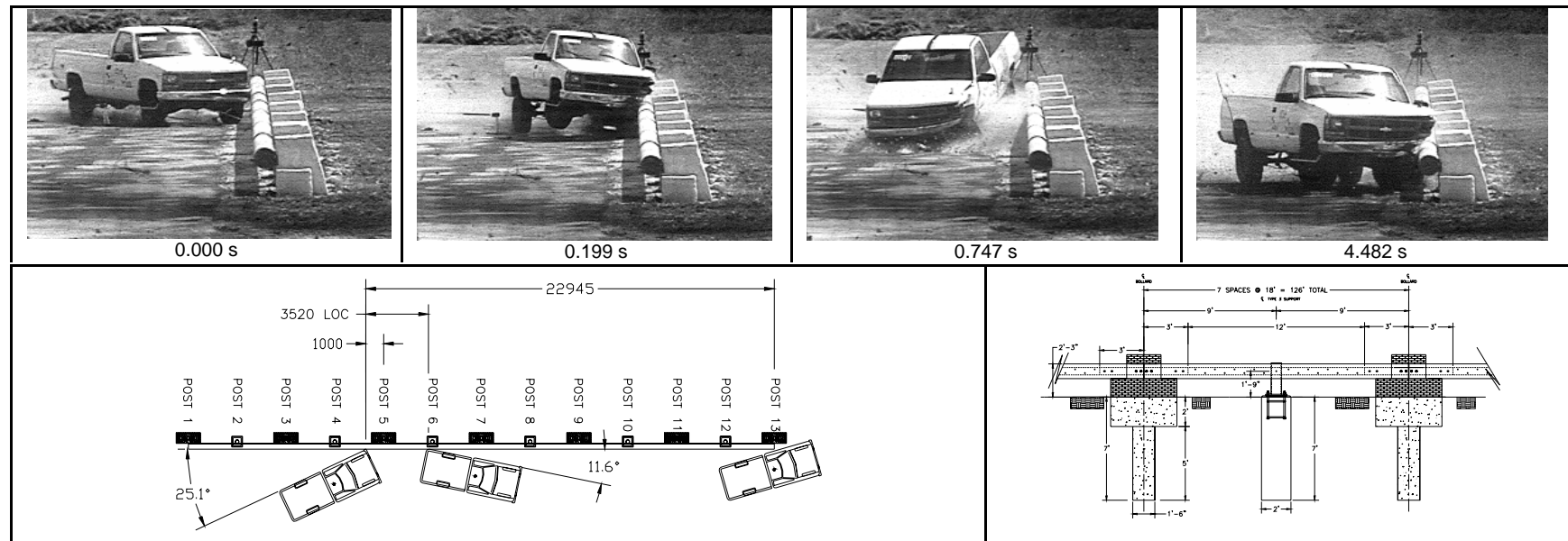


FIGURE 8 (continued) Deception Pass Log Rail details.

**General Information**

Test Agency Texas Transportation Institute
 Test No. 400561-1
 Date 07/01/03

Test Article

Type Guardrail
 Name Deception Pass State Park Log Rail
 Installation Length (ft) 126.0 (38.4 m)
 Material or Key Elements Steel-Backed Log Rail Supported By
 Stone Bollards And Steel Pipe Posts

Soil Type and Condition

Standard Soil, Dry

Test Vehicle

Type Production
 Designation 2000P
 Model 1999 Chevrolet Cheyenne 2500 P/U
 Mass (lb)
 Curb 4686 (2128 kg)
 Test Inertial 4514 (2050 kg)
 Dummy N/A
 Gross Static 4514 (2050 kg)

Impact Conditions

Speed (mi/h) 44.5 (71.6 km/h)
 Angle (deg) 25.1

Exit Conditions

Speed (km/h) 26.9 (43.2 km/h)
 Angle (deg) 11.6

Occupant Risk Values

Impact Velocity (ft/s)
 x-direction 21.0 (6.4 m/s)
 y-direction 17.1 (5.2 m/s)
 THIV (mi/h) 18.1 (29.1 km/h)
 Ridedown Accelerations (g's)
 x-direction -4.0
 y-direction 4.0
 PHD (g=s) 5.2
 ASI 1.29
 Max. 0.050-s Average (g's)
 x-direction -8.7
 y-direction 7.8
 z-direction -7.5

Test Article Deflections (in)

Dynamic Not measurable
 Permanent 0.4 (10 mm)
 Working Width Not measurable

Vehicle Damage

Exterior
 VDS 11FL2
 CDC 11FLEW2
 Maximum Exterior
 Vehicle Crush (in) 25.0 (640 mm)
 Interior
 ODCI LF0102000
 Max. Occ. Compart.
 Deformation (in) 2.3 (58 mm)

Post-Impact Behavior

(during 1.0 s after impact)
 Max. Yaw Angle (deg) 36.4
 Max. Pitch Angle (deg) -9.9
 Max. Roll Angle (deg) -17.1

FIGURE 9 Summary of test results – Test 400561-1.

